

CALLOVIAN COLONIAL CORALS FROM THE TUWAIQ MOUNTAIN LIMESTONE OF SAUDI ARABIA

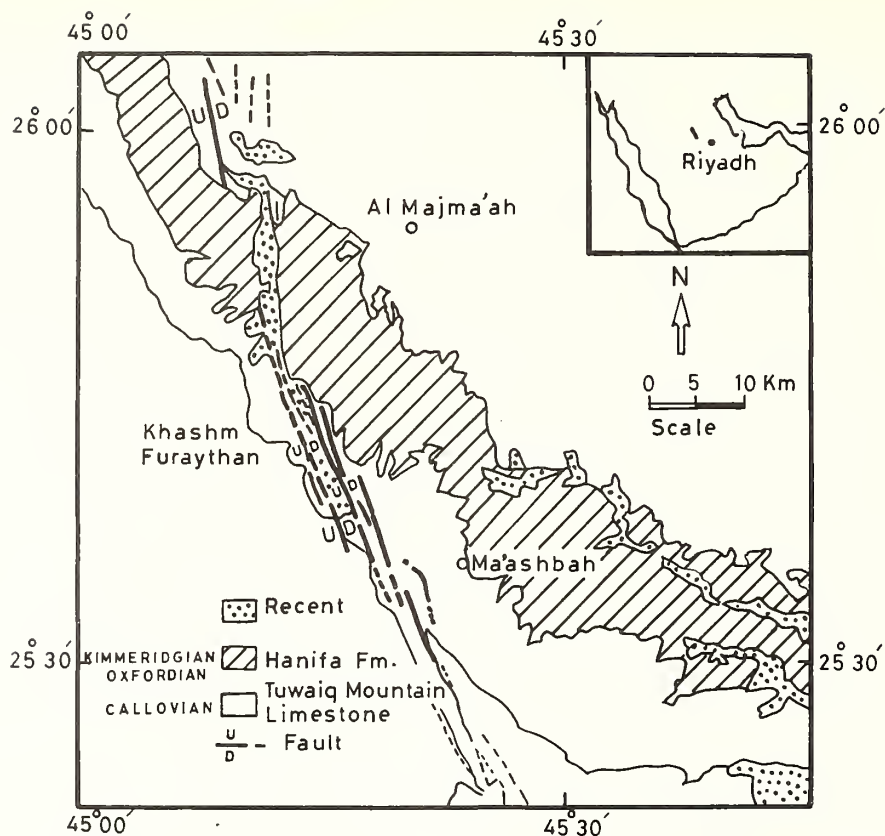
by GHALIB M. A. EL-ASA'AD

ABSTRACT. The earliest development of coral-bearing strata in Central Saudi Arabia took place during deposition of the Tuwaiq Mountain Limestone (upper Middle–Upper Callovian). It does not appear to constitute a major barrier reef, but rather a series of isolated corals and coral bioherms; coral heads (20–50 cm in diameter) are scattered in life position within an extensive sheet of pure limestone (20–40 m thick) stretching for more than 1000 km along strike in Central Saudi Arabia. This sheet could be described as an extensive biostrome. A striking feature of the Tuwaiq Mountain Limestone coral fauna is the low diversity of species that persisted throughout the development of the formation. These species are: *Meandraraea gazaensis* Alloiteau and Farag, *Ovalastraea caryophylloides* Goldfuss, *Trigerastraea collignoni* (Alloiteau), *Columnocoenia lamberti* Alloiteau and *Brachthelia* sp. A possible explanation for the low diversity of the fauna is inimical ecological conditions or palaeobiogeographical barriers which could have prevented the historical accumulation of species from neighbouring areas. Similar factors are responsible also for the endemism of the Jurassic Arabian fauna including ammonites, foraminifers, algae, ostracods, nautiloids, brachiopods and echinoids.

THE earliest development of a coral-bearing barrier system in Central Saudi Arabia took place during deposition of the Upper Tuwaiq Mountain Limestone (Late Callovian). An extensive sheet of coral-bearing, dense, pure, aphanitic limestone (25–40 m thick) caps the formation. Coral heads are scattered commonly in position of growth but ordinarily they make up only a small proportion of the rock as a whole. Small coral bioherms up to 15 m high and about 50 m in diameter are present locally just west of the city of Riyadh (in the Durma region, true metre-high reefs are particularly visible in the cutting made for the Riyadh–Jiddah highway); elsewhere the Upper Tuwaiq Mountain Limestone is micritic and well-bedded. To the south of Riyadh the formation thins and corals become more and more concentrated into rubbly beds in which their remains make up a substantial proportion of the rock. About 200 km to the north of Riyadh (west of the city of Majma'ah) the upper Tuwaiq Mountain Limestone contains a higher proportion of soft limestones. In this area, only the upper part of the formation is preserved in the Majma'ah graben as prominent ridges and erosional remnants. Well-preserved, complete coralla were collected from these erosional surfaces at Khashm Furaythan (text-fig. 1) and these comprise the material used in the present study. Although the stratigraphy and sedimentation of Mesozoic formations in Central Saudi Arabia have been adequately studied, the corals and coral reefs have not previously been investigated. Hitherto, no coral species have been figured from the Tuwaiq Mountain Limestone.

GEOLOGICAL SETTING

The lithostratigraphy of the Tuwaiq Mountain Limestone has been described by Steineke (1937), Arkell (1952), Steineke *et al.* (1958), Powers *et al.* (1966) and Powers (1968). According to Powers *et al.* (1966), the Tuwaiq Mountain Limestone is named after Jabal Tuwaiq, the spectacular, nearly parallel sequence of west-facing scarps developed in the Jurassic rocks of Central Arabia. The Tuwaiq Mountain Limestone itself forms the largest and most persistent of these escarpments and, as such, constitutes the backbone of Jabal Tuwaiq. It has been mapped from lat. 17° 30' N to lat. 27° 30' N, a distance of more than 1200 km. Over most of its extent the limestone forms



TEXT-FIG. 1. Geological map of west Al-Majma'ah, Central Saudi Arabia showing collection site (Khashm Furaythan) (after Bramkamp and Ramirez 1958).

a precipitous west-facing cuesta. The thickness of the Tuwaiq Mountain Limestone reaches a maximum of between 200 and 215 m in the Darb al Hijaz (type locality) to Wadi Nisah (lat. $24^{\circ} 15' N$) area. The formation thins uniformly away from this region to the north and to the south, where it becomes 45–60 m thick at its northern and southern extremities. The Lower Tuwaiq Mountain Limestone comprises a series of fine-grained, fairly clayey limestones intercalated with beds of brown calcarenite and white bioturbated nodular limestone. The Middle Tuwaiq Mountain Limestone comprises a monotonous assemblage of fine-grained or gravelly bioclastic limestones, relatively bioturbated and clayey, containing isolated corals. The Upper Tuwaiq Mountain Limestone consists of very extensive bioclastic limestone and calcarenite, rich in silicified corals and stromatoporoids which locally give rise to reef forms with bioherms in the middle of the basin.

The lower part of the Tuwaiq Mountain Limestone was assigned to the Middle Callovian by Arkell (1952) on the basis of the ammonite *Erynnoceras*, and later by Imlay (1970) on the basis of the ammonites *Pachyceras* cf. *schloenbachi*, *Erynnoceras philbyi* and *Erynnoceras* (*Pachyerynnoceras*) cf. *E. (P.) jarri*. The upper part of the Tuwaiq Mountain Limestone contains two distinctive foraminifers, *Kurnubia wellingsi* (Henson) and *Steinekella steinekei* Redmond, which were considered to be of Oxfordian age by Powers *et al.* (1966). Subsequently, Le Nindre *et al.* (1983) assigned a Middle to Upper Callovian age to the Tuwaiq Mountain Limestone outcrops south of Riyadh, following their record of *Trocholina palastiniensis* (Henson) generally associated with *Kurnubia bramkampii* Redmond from the lower part of the formation, *Kurnubia* cf. *palastiniensis* (Henson) from the middle part, and *Steinkella steinekei* (Redmond) from the coral biostromal facies

in the upper part. In 1986, Enay *et al.* recorded the ammonites *Pachyerymnoceras*, *Erymnoceras* and *Kurnubiella* cf. *hatirae* (Lewy) from the Tuwaiq Mountain Limestone and they assigned an upper Middle–Upper Callovian age (*coronatum* Zone) to the Tuwaiq Mountain Limestone.

SYSTEMATIC PALAEONTOLOGY

The author has followed Beauvais (1980) in the classification of coral genera. All figured specimens are deposited in the collection of the Department of Geology, University of King Saud, Riyadh, Saudi Arabia and are prefixed by KSU. G. COR.

Suborder FUNGINA Verrill, 1865
 Superfamily SYNASTRAEOIDAE Alloiteau, 1952
 Family MICROSOLENIDAE Koby, 1890
 Genus MEANDRARAEA Etallon, 1858

Type species. Meandraraea gresslyi Etallon, 1864.

Meandraraea gazaensis Alloiteau and Farag, 1958

Plate 78, figs. 1–3

1958 *Meandraraea gazaensis* Alloiteau and Farag, p. 97, pl. 13, fig. 2.

Material. KSU. G. COR. 20, 21, two well-preserved coralla from the Upper Tuwaiq Mountain Limestone at Khashm Furaythan.

Description. Colony massive, meandroid. Calicular surface slightly convex, thin epitheca on collines in the central part of calicular surface. Lower surface slightly concave with concentrically wrinkled, thin epitheca. Calices are arranged in short, sinuous series with 2–4 corallite centres; they are either open or closed at their ends. Calicular pits are distinct, small, round, shallow and aligned in single rows. Isolated calices are rare. Corallite centres inside series are not united directly, they are joined by costosepta of adjacent calices. Costosepta are confluent on the colline tops, parallel on colline sides and curved to meet the corallite centres; they are perforated and consist of simple trabeculae. Costosepta are porous, always ornamented by pennules (pennules are ledges, paired on each face of the septum, which run in discontinuous series at right angles to the trabeculae; they are concave upwards with rounded teeth marking the curved outer rims, see Gill (1967, 1977, 1982)), laterally connected by simple synapticulae; synapticulae are few and appear in longitudinal sections perpendicular to septa to be diagonal to the septal plane and not horizontal. No walls between calices. Collines are tholiform, discontinuous and without ambulaera. No columella. Endotheca thin and composed of very fine dissepiments stretched between adjacent septa; their planes are inclined and not at right angles to the septa.

Dimensions. Diameter of corallum, 16–22 cm; height (thickness) of corallum, 5–6 cm; width of the corallite series, 3–10 mm; distance between corallite centres in series, 2–3.5 mm; septal density along the collines, 50–60 in 1 cm.

Family LATOMEANDRIDAE Alloiteau, 1952
 Genus OVALASTRAEA d'Orbigny, 1900

Type species. Astra caryophylloides Goldfuss, 1826.

Ovalastrea caryophylloides (Goldfuss, 1826)

Plate 78, figs. 4–9

1943 *Ovalastrea caryophylloides* Goldfuss; Vaughan and Wells, p. 120, pl. 10, fig. 17.

1964 *Ovalastrea caryophylloides* (Goldfuss); Beauvais, p. 259, pl. 38, fig. 3, text-fig. 53.

Material. KSU. G. COR. 22, 23. Five well-preserved coralla were collected from the Upper Tuwaiq Mountain Limestone at Khashm Furaythan.

Description. Colony massive, plocoid. Lower surface conical with thickly plated growth lamellae and without epitheca. Calicular surface moderately convex. Multiplication of corallites by mono- to tristomodaeal intratentacular budding. Corallites are mono- to tricentric united by costae and perithecal dissepiments. Corallites are of different size and shape (circular, ovate, elongated or subpolygonal); they are surrounded by acute, moderately high exsert margins and separated or surrounded by shallow, very thin ambulacra or intercorallite surfaces. Corallite centres in bi- or tricentric corallites are either united directly by one or two septal lamellae or are not directly united. Radial elements are slightly perforated costosepta; they are long, straight and meet the axial region of the calice at their inner ends; 5–20 short septa join the long ones at their inner margins; a few septa are shorter and free between the long and short ones. Septa bifurcate at the corallite margins and spread as exothecal costae; these costae are sharply confluent on the intercorallite surfaces. Costosepta are slightly perforated and consist of simple trabeculae. Costosepta are pennular, with pennulae (as seen in vertical sections) alternating in a zig-zag pattern along septum. Columella trabecular or spongy. Endotheca composed of fine dissepiments in interseptal spaces; they are strongly inclined. Exothecal dissepiments are numerous and infill intercostal spaces. Synapticulae are horizontal or slightly inclined.

Dimensions. Maximum diameter of corallum, 14–20 cm; height of corallum, 8–12 cm; diameter of corallites, 5–14 mm; distance between calices, 4–12 mm; number of septa, 50–60 in 1 cm.

Family ANDEMANTASTRAEIDAE Alloiteau, 1952

Genus TRIGERASTRAEA Alloiteau, 1951

Type species. *Isastrea trigeri* Fromental, 1887.

Trigerastraea collignoni (Alloiteau, 1958)

Plate 79, figs. 1–3

1958 *Trigerastraea collignoni* Alloiteau, p. 78, pl. 7, fig. 1 and pl. 14, fig. 3.

Material. KSU. G. COR. 24, 25. Three well-preserved, complete coralla were collected from the Upper Tuwaiq Mountain Limestone at Khashm Furaythan.

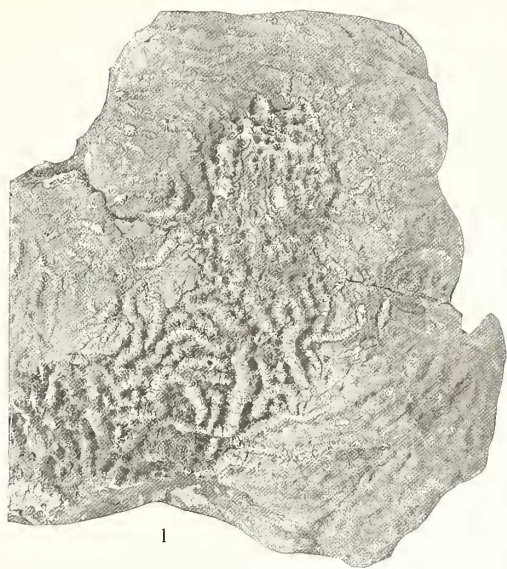
Description. Colony massive, subcerioid, hemispherical, the lower surface moderately concave and covered by a thin epitheca, the calicular surface regular and strongly convex. Multiplication of corallites is by cerioid mono- to distomodocyl or tristomodocyl intratentacular budding producing short corallite series (with 2–3 centres) and numerous isolated calices. Calices are pentagonal, rarely hexagonal or irregular with 4 to 6 unequal, substraight to curved sides. Corallite series are subpolygonal, irregular, and with distinct corallite centres which are united by one or two substraight costosepta. Walls of adjacent isolated calices or series delimit a narrow, shallow, polygonal intercorallite trough (ambulacra) which is 0.5 mm deep and 0.75 mm wide. Radial elements are subconfluent costosepta (48–56), of three different sizes; there are 12–16 straight long septa (S_1) extending to corallite axial organ, and 12–16 short septa (S_2) united to long septa by curving of their inner margins, 24–32 shorter septa (S_3) are inserted between long septa and united to them near the distal margin. Costosepta are pennular, rarely perforated and formed of simple trabeculae. Synapticulae are rare. Lateral faces of septa have granules aligned in rows perpendicular to the margins of the septa. Parietal columella. Endotheca is formed of fine, strongly inclined dissepiments.

EXPLANATION OF PLATE 78

Figs. 1–9. Corals from the Upper Tuwaiq Mountain Limestone (Upper Callovian), Khashm Furaythan, Central Saudi Arabia.

Figs. 1–3. *Meandraraea gazaensis* Alloiteau and Farag, KSU. G. COR. 20. 1, calicular surface, $\times 0.4$. 2, transverse thin section showing corallite series, $\times 10$. 3, longitudinal thin section perpendicular to the septa showing the alternation of pennular level in adjacent septa and the inclined synapticulae, $\times 40$.

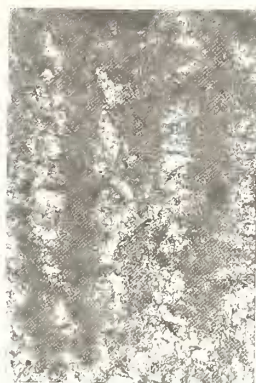
Figs. 4–9. *Ovalastraea caryophylloides* (Goldfuss), KSU. G. COR. 22. 4, calicular surface, $\times 0.6$. 5, detail of calicular surface, $\times 3$. 6, transverse thin section of monocentric calice, $\times 10$. 7, transverse thin section of tricentric calice, $\times 10$. 8, transverse thin section of bicentric calice, $\times 10$. 9, longitudinal thin section perpendicular to the septa showing the alternating pennulae of septa and the slightly inclined planes of the synapticulae, $\times 10$.



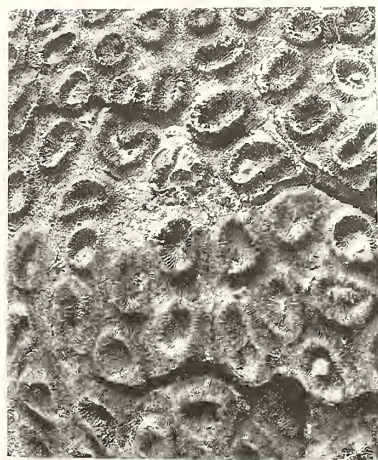
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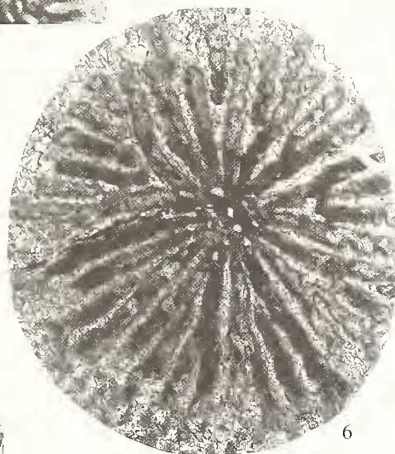
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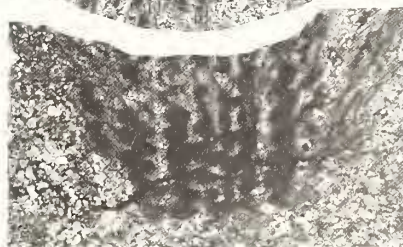
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Dimensions. Diameter of corallum, 20–26 cm; height of corallum, 8–13 cm; larger diameter of isolated calices, 7–13 mm; smaller diameter of isolated calices, 5–10 mm; width of corallite series, 16–22 mm; distance between calicular centres for isolated calices, 5–10 mm; density of septa, 30–40 in 1 cm; number of septa: 48–56.

Suborder STYLININA Alloiteau, 1952

Family AGATHELIIDAE Beauvais and Beauvais, 1975

Genus AGATHELIA Beauvais and Beauvais, 1975

Type species. *Brachthelia collignoni* Beauvais and Beauvais, 1975.

Brachthelia sp.

Plate 79, figs. 4–6

Material. KSU. G. COR. 26. Three well-preserved coralla were collected from the Upper Tuwaiq Mountain Limestone at Khashm Furaythan.

Description. Colony plocoid, multiplication of corallites by intercalicinal budding. Calicular surface moderately convex. Costae are few; they are fairly well-developed only on calicular margins and present within the lamellar peritheca. Peritheca is well-developed, consisting of granular, superposed lamellae; each lamella is built up of single sheets of dissepiments. No exotheca exists between the perithecal lamellae. Radial elements are compact costosepta arranged hexamerally into six subequal groups; each group consists of four septa [$1(S_1)$, $1(S_2)$ and $2(S_3)$]. S_1 and S_2 are subequal and united at their inner margins to the axial organ of the calice. S_3 are shorter (one half length of S_1) and they are united with S_1 and S_2 at the midlength of S_1 and S_2 . Distal margins of the radial elements are ornamented with thin, rounded and equidistant teeth. Axial organ is a large, elliptical, styliform columella. Endotheca is rarely developed. Wall septothecal.

Dimensions. Diameter of corallum, 20–25 cm; height of corallum, 12–14 cm; diameter of corallites, 5–12 mm; distance between corallite centres, 8–12 mm; number of septa, 24.

Discussion. This species is distinguished by its type of radial symmetry which is characteristic of the suborder Stylinina Alloiteau, 1952, and by its lamellar peritheca which characterizes the genus *Brachthelia* Beauvais and Beauvais, 1975. The extremely low diversity of *Brachthelia* species together with the poor material collected from Central Arabia makes the erection of a new species inadvisable.

Suborder FAVIINA Vaughan and Wells, 1943 (= ASTRAEOIDA Alloiteau, 1952)

Family PLACOCAENIIDAE Alloiteau, 1952

Genus COLUMNOCOENIA Alloiteau, 1952

Type species. *Columnocoenia lamberti* Alloiteau, 1952.

EXPLANATION OF PLATE 79

Corals from the Upper Tuwaiq Mountain Limestone (Upper Callovian), Khashm Furaythan, Central Saudi Arabia.

Figs. 1–3. *Trigerastraea collignoni* (Alloiteau), KSU. G. COR. 24. 1, calicular surface, $\times 0.7$. 2, transverse thin section of bicentric calice, $\times 10$. 3, longitudinal thin section perpendicular to the septa showing alternating pennulae and strongly inclined dissepiments, $\times 40$.

Figs. 4–6. *Brachthelia* sp., KSU. G. COR. 26. 4, calicular surface, $\times 1$. 5, transverse thin section of corallite showing the radial symmetry of the septa, $\times 10$. 6, side view of corallum, $\times 0.5$.

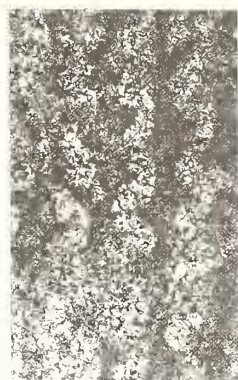
Figs. 7–9. *Columnocoenia lamberti* Alloiteau, KSU. G. COR. 27. 7, part of calicular surface, $\times 1$. 8, detail, $\times 4$. 9, longitudinal thin section showing pennular septa and dissepiments, $\times 20$.



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Columnocoenia lamberti Alloiteau, 1957

Plate 79, figs. 7–9

1957 *Columnocoenia lamberti* Alloiteau, p. 135, pl. 7, fig. 5.

Material. KSU. G. COR. 27. Six well-preserved coralla were collected from the Upper Tuwaiq Mountain Limestone at Khashm Furaythan.

Description. Colony massive, plocoid. Calicular surface convex. Multiplication of corallites is by extracalicular budding. Corallites almost cylindrical and united by well-developed peritheca. Calices are joined together by confluent to subconfluent, thick and well-developed costae; calices are generally large in size and rounded. Radial elements are compact costosepta with a few perforations at their axial ridges; arranged in radial and bilateral symmetry into equal systems; there are six primary, thick and calviform septa (S_1) alternating with six secondary septa (S_2); S_1 and S_2 are free and bifurcate into 24 tertiary septa (S_3). Upper margins of septa are dentate with strong and widely spaced teeth; lateral faces are ornamented with spiniform granules arranged into a few rows. There are thick and slightly elongated pali surrounding the axial organ; pali are located at the axial ends of S_1 and S_2 . Columella thick, lamellar and anastomosing with two diametrically opposed S_1 forming a continuous lamella and dividing the calice into two equal parts. Endotheca is rare. Exotheca thick with abundant dissepiments, especially in the lower part of corallum. Wall is continuous (septo and synapticulothecal).

Dimensions. Diameter of corallum, 11–20 cm; height of corallum, 6–10 cm; diameter of calices, 5–7 mm; distance between corallite centres, 8–13 mm; number of septa, $6S_1 + 6S_2 + 24S_3$.

DISCUSSION

The Arabo-Nubian Massif and the Tethys Sea were the two main factors controlling sedimentation in Saudi Arabia during Mesozoic times. The succession in the Jurassic basin of Central Saudi Arabia is divided into the Lower Jurassic Marrat Formation, the Middle Jurassic Dhurma Formation and Tuwaiq Mountain Limestone, and the Upper Jurassic Hanifa Formation, Jubaila Limestone, Arab Formation and Hith Anhydrite (Bramkamp and Steineke *in* Arkell 1952; Powers *et al.* 1966; Powers 1968). Jurassic outcrops in Central Saudi Arabia are arranged in a convex arc hinged on the Al-Riyadh region with the horns of the arc orientated to the north-west and to the south. The total outcrop length is in excess of 1000 km and the width nowhere exceeds 85 km. The greatest outcrop width and thickness (1100 m thick) are in the Al-Riyadh region. This represents the area closest to the open sea domain of the Tethys which was located to the north-east of Riyadh, mostly underlying the present day Arabian Gulf.

The Jurassic basin of Central Saudi Arabia was a young basin during deposition of the Lower Marrat Formation and Upper Dhurma Formation (Toarcian–Lower Bathonian), a mature basin during deposition of the Upper Dhurma Formation and Lower Hanifa Formation (Middle Bathonian–Middle Oxfordian), and an old basin when the Upper Hanifa Formation and the Hith Anhydrite (Upper Oxfordian–Tithonian) were deposited. The latter phase is one of basin closure accompanied by epeirogenic phenomena and ending with the Sabkah landscape of the Hith Anhydrite (Powers *et al.* 1966; Enay *et al.* 1986).

During the Callovian, a broad shallow sea along the southern flank of the Tethys deposited clastic-rich limestones from Central Arabia eastwards to Iran and Oman, and southwards across Yemen and Aden. Similar neritic limestones extend north through Central Iraq (Powers *et al.* 1966). In Central Saudi Arabia during the deposition of the Tuwaiq Mountain Limestone (upper Middle–Upper Callovian), this broad shallow sea deposited very extensive bioclastic limestones and calcarenites, rich in silicified corals and stromatoporoids. The upper part of these limestones forms an extensive coral biostrome extending for more than 1000 km in Central Saudi Arabia and locally includes small bioherms. Fossils of shallow water organisms are abundant in the Tuwaiq Mountain Limestone; those associated with the coral biostrome are listed in Table 1.

The extensive bioclastic limestones of the Tuwaiq Mountain Limestone with abundant remains of shallow water organisms show that shoaling of the sea floor persisted throughout the deposition

TABLE 1. Shallow-water fauna associated with the coral biostrome of the Upper Tuwaiq Mountain Limestone in Central Saudi Arabia

AMMONITES (Enay *et al.* 1986)*Pachyerymnoceras* sp., *Erymnoceras doliforme* Roman.

NAUTILOIDS (Tintant 1987)

Paracenoceras aff. *dilatatum* Jeannet, *P.* aff. *dorsoexcavatum* (Parona and Bonar).

BRACHIOPODS (Almeras 1987)

Striithyris somaliensis Muir Wood, *Thadigithyris thadigiensis* Nazer, *Kutchirhynchia indica* (d'Orbigny), *Bihenithyris weiri* Muir Wood.

ECHINOIDS (Kier 1972)

Polycyphus parvituberculatus Kier, *Rhabdocidaris mogharensis* Fourt, *Bothryopneustes orientalis* Fourt, *Pygurus smelliei* Currie, *Pseudocidaris* aff. *choffati* (de Loriol).FORAMINIFERA (Le Nindre *et al.* 1987)*Nautiloculina oolithica* Mohler, *Kurnubia bramkampi* Redmond, *K. palastiniensis* Henson, *K. wellingsi* Henson, *Trocholina palastiniensis* Henson, *Steinekella steinekei* Redmond, *Conicospirillina basiliensis* Mohler, *Everticyclammina* sp.BIVALVES (Le Nindre *et al.* 1987)*Protocardia* gr. *hullamum* (Sowerby), *Lopha solitaria* (Sowerby), *Ceratomyopsis* cf. *arabica* Cox, *Chlamys nattheimensis* (de Loriol), *C.* cf. *curvivarans* Dietr., *Inoperna* cf. *sowerbyana* (d'Orbigny), *Modiolus imbricatus* (Sowerby), *Pholadomya lirata* (Sowerby), *P. protei* Brongniart, *Mactromya* cf. *crassa* Agassiz, *Pseudotrachezium* cf. *cardiformis* (Douville), *Acromytilus somaliensis* Cox, *A. laitmairensis* (de Loriol), *Mytilus* cf. *jurensis* Roemer.GASTROPODS (Le Nindre *et al.* 1987)*Discohelix douvillei* Cossmann, *Globularia hemisphaerica* (Roemer), *Nerinea bruntrutana* (Thurmann), *Cossmannia* cf. *tuberculata* (Defrance), *Ampullospira* sp., *Aporrhais* sp., *Pseudomeliana* sp., *Harpogodes* sp., *Bourguetia* sp., *Trochus* sp., *Vermetus* sp., *Pietteia* sp.

of the formation. It seems that this slow subsidence of the sea floor did not provide adequate space for the build up of a true reefal barrier system in Central Saudi Arabia. Although the Tuwaiq Mountain Limestone displays varied palaeoenvironments (back reefal, sheltered lagoonal, outer lagoonal and reefal, see Enay *et al.* 1986), its main characteristic lies in the coral biostromal deposits which widely transgress the margins of the basin.

A striking feature of the Tuwaiq Mountain Limestone coral fauna is that a low diversity of species (five species) persisted throughout the development of the formation. This low diversity coral fauna is the result of interacting factors related to the palaeobiogeography and the palaeoenvironmental conditions of a very shallow platform. Changes of palaeoenvironmental conditions on a very shallow platform together with the adaptation of fauna to this very shallow platform palaeoenvironment are responsible for the endemism of the Jurassic Arabian fauna as a whole.

The endemism of the Jurassic Arabian fauna, and more widely the Jurassic fauna of the entire Middle East, is well-known; it is prominent in the best studied fossil groups such as ammonites, foraminifers, and ostracods, but less so in nautiloids and brachiopods (Enay 1987). Indeed, the endemism of the Arabian fauna has been used as a justification by Kier (1972) for creating new species and genera of echinoids.

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REFERENCES

- ALLOITEAU, J. 1952. Madréporaires post-Paléozoïques. In PIVETEAU, J. (ed.). *Traité de paléontologie*, 1, 539–782. Masson, Paris.
- 1957. *Contribution à la systématique des Madréporaires fossiles*, 1. 462 pp., pls. 1–20. C.N.R.S., Paris.
- 1958. Monographie des Madréporaires fossiles de Madagascar. *Annls géol. Madagascar*, 25, 1–218. Paris.
- and FARAG, I. 1958. Monographie des polypiers Jurassiques d’Egypte. *Bull. Inst. Egypte*, 39, 50–130.
- ALMÉRAS, Y. 1987. Les brachiopodes du Lias-Dogger. Paléontologie et biostratigraphie. In ENAY, R. (ed.). Le Jurassique d’Arabie saoudite centrale. *Geobios*, mém. spéc. 9, 161–219.
- ARKELL, W. J. 1952. Jurassic ammonites from Jebel Tuwaiq, Central Arabia. *Proc. R. Soc. (B)*, 236, 241–313.
- BEAUVAIS, L. 1964. Étude stratigraphique et paléontologique des formations à Madréporaires du Jurassique supérieur du Jura et de l’Est du Bassin de Paris. *Mém. Soc. géol. Fr.*, 43, 1–288. Paris.
- and BEAUVAIS, M. 1975. Une nouvelle famille dans le sous-ordre des *Stylinida* Alloiteau: Les *Agatheliidae* nov. fam. (Madréporaires Mésozoïques). *Bull. Soc. géol. Fr.*, sér 7, 17, 576–581.
- — 1980. Sur la taxonomie des Madréporaires Mésozoïques. *Acta palaeont. pol.* 25, 345–360.
- BRAMKAMP, R. and RAMIREZ, L. F. 1958. Geology of the Northern Tuwaiq Quadrangle, Kingdom of Saudi Arabia. *United States Geological Survey Miscellaneous Geologic Investigations Map* 1-207 A.
- ENAY, R. (ed.) 1987. Le Jurassique d’Arabie saoudite centrale. *Geobios*, mém. spéc. 9, 1–316.
- , LE NINDRE, Y.-M., MANGOLD, C., MANIVIT, J. and VASLET, D. 1986. The Jurassic of Central Saudi Arabia: new data on lithostratigraphic units, paleoenvironments, ammonite faunas, ages, and correlations. *Deputy Ministry Miner. Res.*, Jiddah, Technical Record BRGM-TR-06-3, 65 pp.
- GILL, G. A. 1967. Quelques précisions sur les septes perforés des polypiers Mésozoïques. *Mém. Soc. géol. Fr.*, 106, 55–83.
- 1977. Essai de regroupement des Stylines (Hexacoralliaires) d’après la morphologie des bords internes de leurs septes. *Mém. Bur. Rech. géol. minière*, 89, 283–295.
- 1982. A supposed rhythmic mechanical process in coral skeletal growth. In GALLITELLI, E. M. (ed.). *Palaeontology, essentials of historical geology*, 445–466. Mucchi, Modena.
- IMLAY, R. W. 1970. Some Jurassic ammonites from Central Saudi Arabia. *Prof. Pap. U.S. geol. Surv.* 643, D1–15.
- KIER, P. M. 1972. Tertiary and Mesozoic echinoids of Saudi Arabia. *Smithson. Contr. Paleobiol.* 10, 1–242.
- LE NINDRE, Y.-M., MANIVIT, J. and VASLET, D. 1987. Histoire géologique de la bordure occidentale de la plate-forme arabe du paléozoïque inférieur au Jurassique supérieur. 4 vols, 1122 pp. Theses de Doct. Etat (unpubl.), Université P. et M. Curie, Paris.
- VASLET, D. and MANIVIT, J. 1983. Sedimentary evolution of Saudi Arabia Jurassic (Toarcian–Upper Oxfordian) deposits in outcrop between latitudes 24° N. and 22° N. *Saudi Arabian Deputy Ministry Mineral Resources*, Jiddah, Open-file report BRGM-OF-03-5, 34 pp.
- POWERS, R. W. 1968. *Lexique stratigraphique international*, 3, Asie, fasc. 10bl: Saudi Arabia, 177 pp. C.N.R.S., Paris.
- RAMIREZ, L. F., REDMOND, C. D. and ELBERG, E. L. JR. 1966. Geology of the Arabian peninsula, sedimentary geology of Saudi Arabia. *Prof. Pap. U.S. geol. Surv.* 560-D, 1–147.
- STEINEKE, M., BRAMKAMP, R. A. and SANDER, N. J. 1958. Stratigraphic relations of Arabian Jurassic oil. In WEEKS, L. G. (ed.). *Habitat of oil*, 1294–1329. American Association of Petroleum Geologists, Tulsa.
- TINTANT, H. 1987. Les Nautilés Jurassiques d’Arabie saoudite. In ENAY, R. (ed.). Le Jurassique d’Arabie saoudite centrale. *Geobios*, mém. spéc. 9, 67–159.
- VAUGHAN, T. W. and WELLS, J. W. 1943. Revision of the suborders, families and genera of the Scleractinia. *Spec. Pap. geol. Soc. Am.*, 44, 1–363.

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